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Maciej MAJOR[1], Mariusz KOSIŃ[2], Izabela MAJOR[3]

NUMERICAL STATIC ANALYSIS OF THE CURTAIN WALL WITH LIGHT STEEL STRUCTURE

Abstract

This paper presents a numerical analysis of the effect of wind on the curtain wall in a high building. Two types of curtain wall were adopted: made of thin-wall C sections with nominal dimensions and the section that takes into consideration lower limits specified by the manufacturer.

Keywords

Thin-walled construction, curtain wall, FEM, wind pressure.

1 INTRODUCTION

The role of curtain walls is to protect the building from climatic and acoustic effects. The connected panels of a curtain wall with the load-bearing structure form a light and continuous sheathing that closes the space [1]. They perform the function of the external wall while not bearing its whole role but only its own weight and wind pressure. One of the frequent mistakes during the design of such structures is no verification of the data contained in the manufacturer's catalogues. This leads to mistakes in terms of connections between the components, including curtain walls, and, sometimes, incorrect dimensioning. The values of geometric characteristics tend to be overestimated for thin-wall steel sections and the studies contain mistakes that point to their improper assembly. Since the curtain walls have been used in increasingly high buildings, the pressure should be on elimination of this type of mistakes.

This study presents a numerical analysis of the effect of wind on the curtain wall in a high building. Two types of curtain wall were adopted: made of thin-wall C sections with nominal dimensions and the section that takes into consideration lower limits specified by the manufacturer. Numerical model of curtain wall is analysed in ANSYS software based on the FEM method which is widely used to analysis of building structures [2, 3].

2 ASSUMPTIONS TO ANALYSIS

The analysis concerned the curtain wall with height of 3.06 m made as a light steel structure (see Fig.1).

The analysis also adopted two thin-wall C sections with dimensions shown in Tab. 1 arranged with distances of 60 cm.

[1] Assoc. Prof. Eng. Maciej Major, Ph.D., Częstochowa University of Technology, Faculty of Civil Engineering, Department of Steel Constructions and Building Materials, Akademicka 3 street, 42-200 Częstochowa, Poland, phone: (+48) 34 3250 965, e-mail: mmajor@bud.pcz.czest.pl.

[2] MSc. Eng. Mariusz Kosiń, Częstochowa University of Technology, Faculty of Civil Engineering, Department of Organization and Building Technology, Akademicka 3 street, 42-200 Częstochowa, Poland, e-mail: mariuszkosa@vp.pl.

[3] Assoc. Prof. Eng. Izabela Major, Ph.D., Częstochowa University of Technology, Faculty of Civil Engineering, Department of Technical Mechanics and Engineering Graphics, Akademicka 3 street, 42-200 Częstochowa, Poland, phone: (+48) 34 3250 901, e-mail: imajor@bud.pcz.czest.pl.

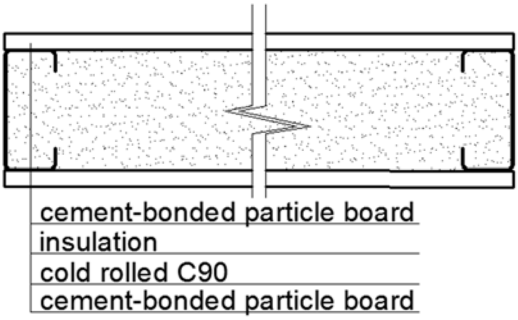
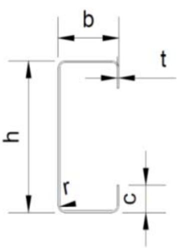


Fig.1: The scheme of curtain wall construction

Tab.1: The dimensions adopted for the analysis of thin-walled steel sections of C type

	Designation of the analyzed section	Geometric parameters of sections					Cross section area
		h [mm]	b [mm]	c [mm]	t [mm]	r [mm]	A [cm^2]
	Section I	89	38	16	0.90	3	1.687
	Section II	86.5	36.5	14.5	0.90	3	1.620

It was assumed that the building is located in the first zone of wind load in a city centre at the altitude of 200 meters above sea level with the category 4 land development. Calculations of the structural coefficient $c_s c_d$ were made according to the Procedure 1 of the Appendix B of the PN-EN 1991-1-4 standard. The values of the parameters calculated according to the equations contained in the European standard [4] necessary for determination of the strength of wind effect were presented in Tab. 2.

Tab.2: List of parameters to calculate the pressure of wind

Designation	**Parameter**	**Point of norm / formula PN EN 1991-1-4**
$v_{b,o}$	Base speed of wind	NA.1[(1)]
$v_m(z)$	The average speed of wind	4.3
$c_s c_d$	Construction coefficient	B.4
$c_e(z)$	Exposure coefficient	NA.3[(1)]
$q_p(z)$	The peak value of pressure	4.5
c_{pe}	The coefficient for the loaded surface	7.2.2[(2)]
w_e	Wind pressure acting on the outer surface of the structure	5.2

[(1)] Domestic annex of norm PN-EN 1991-1-4, [(2)] Coefficient for area A = 1 m^2

Profile of peak values of wind velocity pressure are presented in Fig. 2 [5].

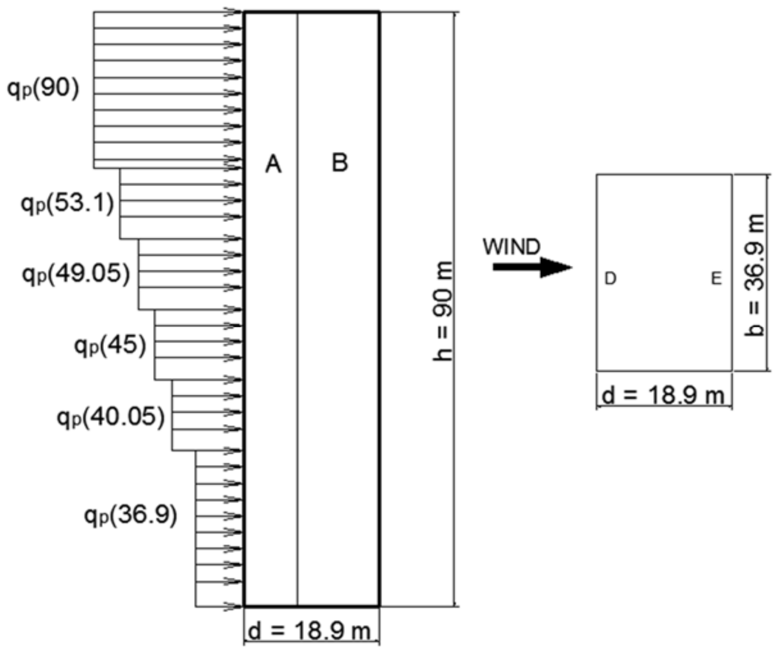


Fig.2: Distributions of velocity pressure $q_p(z)$

Tab. 3 presents the horizontal load to the building used as a reference to calculate the values of the structural coefficient c_sc_d.

Tab.3: Value of the wind pressure w_e for A = 1 m^2 and for fields of vertical walls A, B, D and E

z_e [m]	$q_p(z_e)$ [kN/m^2]	c_sc_d	$c_{pe,1}$ A	$c_{pe,1}$ B	$c_{pe,1}$ D	$c_{pe,1}$ E	w_e(A) [kN/m^2]	w_e(B) [kN/m^2]	w_e(D) [kN/m^2]	w_e(E) [kN/m^2]
90	0.860	0.841	-1.4	-1.1	+1.0	-0.68	-1.012	-0.796	+0.723	-0.492
53.1	0.738						-0.868	-0.683	+0.621	-0.422
49.05	0.721						-0.849	-0.667	+0.606	-0.412
45	0.703						-0.828	-0.650	+0.591	-0.402
40.95	0.684						-0.805	-0.633	+0.575	-0.391
36.9	0.663						-0.781	-0.613	+0.558	-0.379

The calculations were based on the wind load, wall cover weight, the weight of thin-wall section and filling (mineral wool). Volumetric weights of materials were adopted according to [6] and according to the manufacturer's specifications. The static strength analysis adopted the wind pressure $w_e(A)$ = -1.012 kN/m^2 calculated for small components and connectors with the surface area of components of 1 square metre or smaller. The loads characteristic for the analysed curtain wall are presented in Tab. 4.

The specifications of the materials used for their analysis with their physical properties are presented in Tab. 5.

Tab.4: Characteristic loads for the analyzed curtain wall

Type of load	Characteristic load [kN/m]
Constant loads	
Plate CETRIS BASIC, thickness 0.012 m with volume weight 13.5 kN/m^3	0.104
Steel thin-walled section of C type	0.013
Mineral wool, thickness 0.089 m with volume weight 1 kN/m^3	0.0534
Variable loads	
Wind load (0.6m×1.012kN/m^2)	0.607

Tab.5: Physical properties of materials of curtain wall

Material	Density [kg/m^3]	Young's modulus E [MPa]	Poisson's ratio υ
Cement-splinter plate	1350	6.8	0.2
Steel thin-walled section	7850	210000	0.3
Mineral wool	100	1.8	0.2

3 NUMERICAL MODEL

Numerical model of the curtain wall was composed of ca. 110,000 nodes and 50,000 elements [7, 8, 9]. The analysis performed is of a static nature within the linear limits of the material's elasticity. The finite component grid for the analysed curtain wall was presented in Fig. 3.

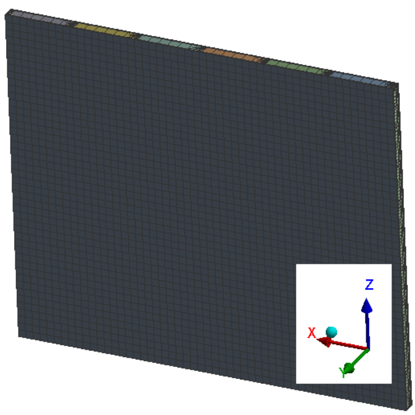


Fig.3: Numerical model of curtain wall analysed in ANSYS software

The numerical model of the analysed curtain wall takes into consideration two static designs presented in Fig. 4.

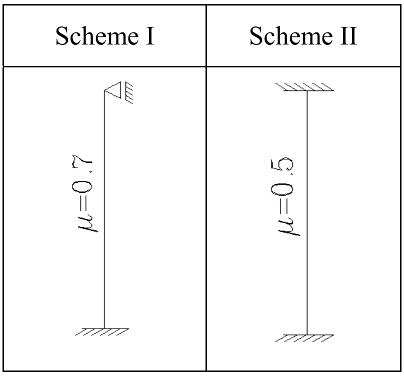


Fig.4: Static schemes for analyzed curtain wall

4 NUMERICAL RESULTS

Numerical simulation of deformation of the curtain wall was performed using the ANSYS software. The Figs. 5-8 below presents the maps of displacements for the analysed curtain wall.

a) b)

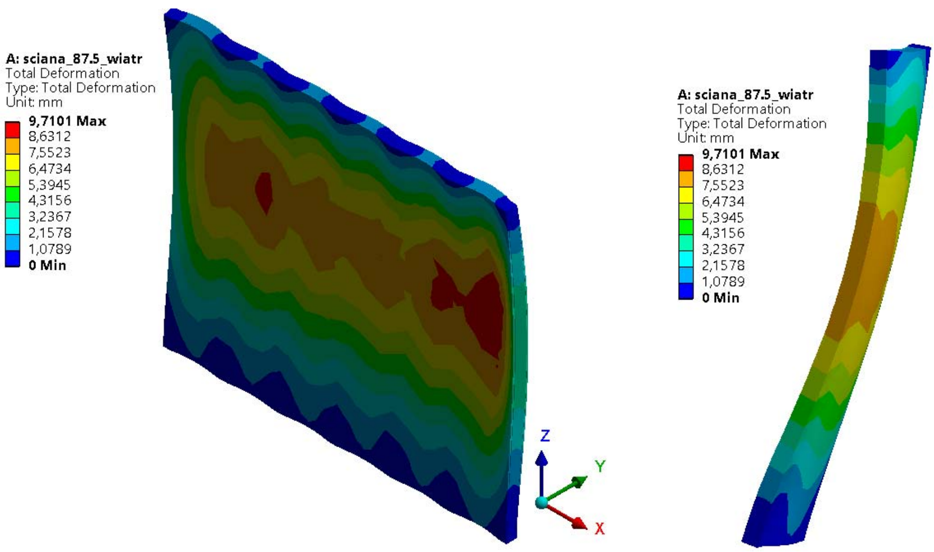


Fig.5: Deflection map (scale of 1:35) for the curtain wall made of thin-wall sections with the cross-section area of A = 1.620 cm^2 for the rod according to the scheme I: a) curtain wall panel, b) cross-sectional view of the steel section present in the half of the wall

Figures 7 and 8 show the differences in the value of deflection. This is caused by the arrangement of the closing section for the analysed curtain wall: the web of the closing section is always oriented outwards.

Calculations connected with dimensioning of the thin-wall section were performed using the ROBOT software. The dimensioning was performed for the greatest pressure of the wind acting on the external surface of the structure with consideration for the weight of the section and wall sheathing plates [8]. The sections were calculated for the static designs presented in Fig. 4 assuming three steel grades: S235, S355 and S460.

a) b)

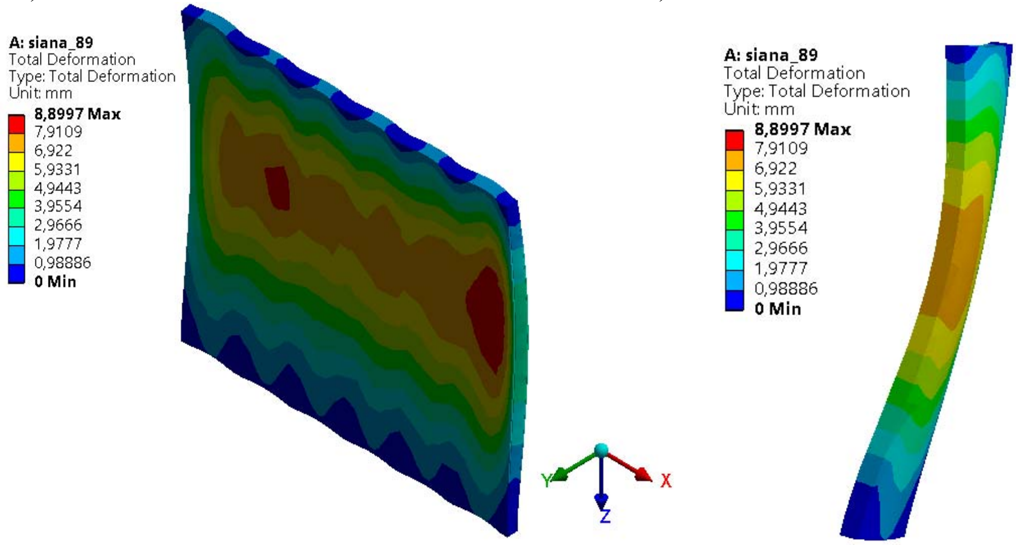


Fig.6: Deflection map (scale of 1:35) for the curtain wall made of thin-wall sections with the cross-section area of A = 1.687 cm^2 for the rod according to the scheme I: a) curtain wall panel, b) cross-sectional view of the steel section present in the half of the wall

a) b)

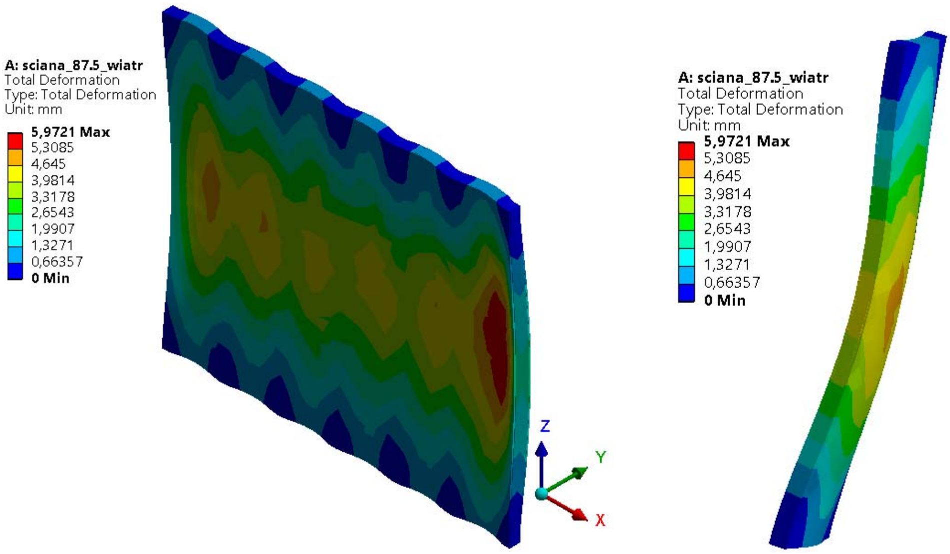


Fig.7: Deflection map (scale of 1:35) for the curtain wall made of thin-wall sections with the cross-section area of A = 1.620 cm^2 for the rod according to the scheme II: a) curtain wall panel, b) cross-sectional view of the steel section present in the half of the wall

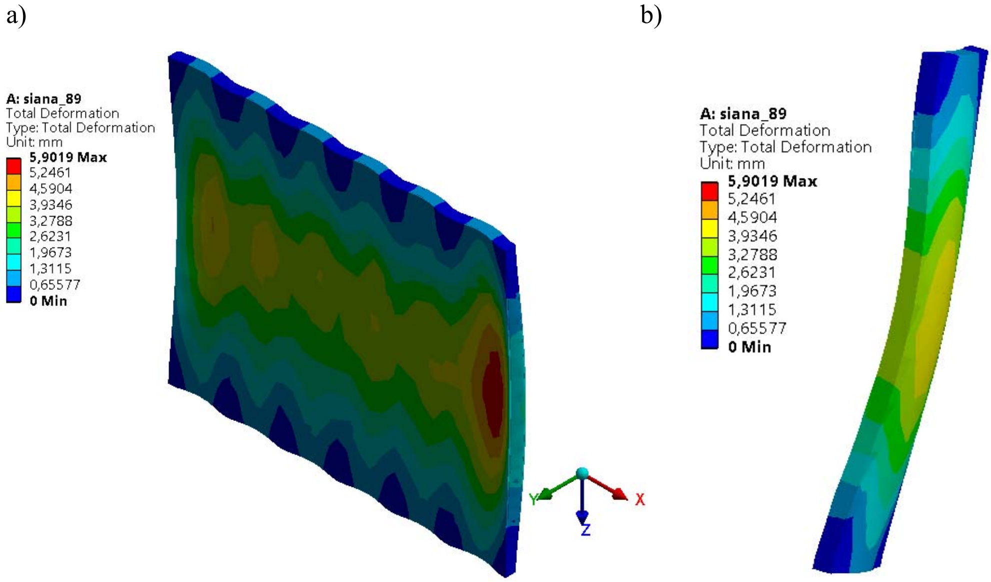


Fig.8: Deflection map (scale of 1:35) for the curtain wall made of thin-wall sections with the cross-section area of A = 1.687 cm^2 for the rod according to the scheme II: a) curtain wall panel, b) cross-sectional view of the steel section present in the half of the wall

5 CONCLUSIONS

The aim of the numerical analysis was to identify the deformations of the curtain wall panels made of thin-wall steel sections with the cross-section area of A = 1.620 cm^2 for the Section I and A = 1.687 cm^2 for the Section II (see Tab. 1).

Tab.6: Summary of the results of the static-strength analysis

Static scheme	Cross section area [cm^2]	Steel grade	Internal forces(3) M_{max} [kN/m]	Internal forces(3) T_{max} [kN]	Max. deflection(4) [mm]	Strain(3) [%]	Admissible
Scheme I	1.687(1)	S235	-1.066 +0.599	-1.045 +1.741	8.900	151	NO
		S355				111	NO
		S460				96	YES
	1.620(2)	S235			9.710	158	NO
		S355				117	NO
		S460				100	NO
Scheme II	1.687(1)	S235	-0.710 +0.355	-1.393 +1.393	5.902	100	NO
		S355				74	YES
		S460				64	YES
	1.620(2)	S235			5.972	105	NO
		S355				78	YES
		S460				66	YES

(1) Section size 89 mm × 38 mm × 16 mm and thickness 0.09 mm, (2) Section size 86.5 mm × 36.5 mm × 145 mm and thickness 0.09 mm, (3) The results obtained in the ROBOT software, (4) Results of the analysis in the ANSYS software.

Table 6 presents the results of simulations and acceptability of using the sections in curtain wall based on the assembly method (according to Fig. 4), surface area and adopted steel grade.

The static strength analysis shows clearly the static designs, steel sections and structural steel grades which fulfil the requirements concerning section strength and stability of the analysed curtain wall. The differences in dimensions of the sections that results from the deviations from the nominal dimension and catalogue errors may lead to a substantial reduction in the rigidity and load-bearing capacity of the component and causing the structure of the curtain wall to locally fail to meet the requirements concerning the limits of load-bearing capacity. The analyses presented in the study show that it is useful to verify the information contained in the manufacturer's documents. The FEM method can be employed in the analysis of thin-wall profiles to verify calculations [10] and assumptions of the study for the adopted model [11, 12].

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